IMPROVED SCENE IDENTIFICATION FOR THE CERES ERBE-LIKE PRODUCT

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1. INTRODUCTION

Accurate determination of cloud properties is important for global radiation budget observing systems such as the upcoming Clouds and the Earth's Radiant Energy System (CERES) and its predecessor, the Earth Radiation Budget Experiment (ERBE). In order to derive radiative flux from satellite-based observations of radiance, it is necessary to use angular dependence models (ADMs) to account for anisotropy. Since the anisotropic characteristics of the radiation field are strongly dependent on the amount and type of clouds observed, it is important that the cloud field be properly identified to ensure the use of the proper ADM.

The selection of ADMs was the primary purpose for the scene identification scheme used by ERBE. However, the identification of clear-sky scenes allowed the calculation of separate total-sky and clear-sky monthly mean fluxes which have been used to study cloud-radiative forcing effects (Ramanathan et al., 1989). Errors due to misclassification of cloud conditions could lead to biases in cloud-radiative forcing estimates.

For CERES, two separate products will be produced using different cloud information (Wielicki et al., 1996). One product will use imager data to derive extensive cloud statistics for each CERES footprint. CERES will also produce an "ERBE-like" product that will define the cloud field using only the CERES broadband fluxes in a manner consistent with that used by ERBE.

The ERBE cloud identification algorithm requires climatological longwave (LW) and shortwave (SW) clear-sky thresholds. ERBE data were processed using zonal-seasonal mean LW thresholds. The coarseness of these thresholds produces seasonally and longitudinally biased reductions in the number of ERBE observations classified as clear. The lack of scenes being classified as clear is particularly severe for observations of land regions at night. This lack of clear-sky coverage could have an impact on cloud forcing estimates derived from the ERBE data set.

New LW thresholds have been produced in order to avoid this problem for CERES. Sixty months of ERBE data from the Earth Radiation Budget Satellite (ERBS) were used to produce a new set of monthly, regional clear-sky LW thresholds. These new thresholds were used to reprocess one month of ERBE scanner data. The development of these thresholds and their effect on the ERBE data set and the CERES ERBE-like processing are discussed below.

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2. ERBE SCENE IDENTIFICATION

The scene identification for the CERES ERBE-like product is performed using the Maximum Likelihood Estimation (MLE) technique of Wielicki and Green (1989). This method compares the observed LW and SW ERBE radiances with *a priori* statistics derived from Nimbus-7 ERB radiometer data. The MLE classifies each ERBE footprint as either clear (0-5% cloud cover), partly cloudy (5-50%), mostly cloudy (50-95%), or overcast (95-100%).

Although the MLE is not strictly a simple threshold technique, the LW and SW threshold values assumed for each ERBE region are obviously of particular importance. Although the SW thresholds vary regionally, the LW thresholds, are zonal, seasonal means of the noontime LW clear-sky flux. For times of the day other than noon, the LW threshold is calculated by:

$$M_t = M_{noon} - \Delta M (\cos \theta_{noon} - \cos \theta_t) \qquad (1)$$

where M_{noon} is the noontime clear-sky LW flux threshold and θ_{noon} and θ_t are the solar zenith angles at noon and time, t. The diurnal range (ΔM) is assumed to be a constant for a given scene type (ΔM = 67 Wm^{-2} for desert, 33 Wm^{-2} for land, and 0 Wm^{-2} for oceans and ice).

During daylight hours, the MLE uses both LW and SW information. Since cold, dark scenes can still be interpreted as clear, misclassification due to errors in the LW threshold can be minimized. For nighttime scene identification, only the LW observation is available for scene identification and realistic LW thresholds become critical.

Although the MLE has been shown to produce scene identification suitable for the selection of ADMs, the coarseness of the LW thresholds can lead to biases in the estimation of clear-sky flux. Specifically, the LW thresholds used during the processing of the ERBE data appear to be extremely conservative. A monthly mean estimate of clear-sky LW flux is calculated for ocean regions even if there is only one observation for the

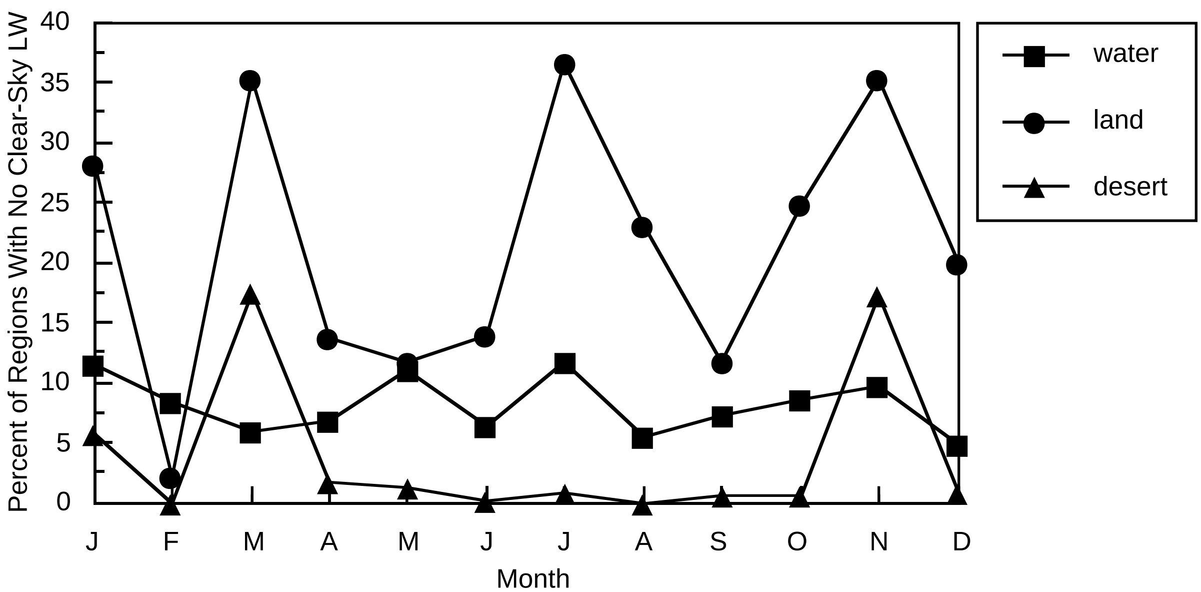

Figure 1. Average percentage (by month) of ERBE regions observed by ERBS with no monthly mean clear-sky LW flux estimate for the years 1985 - 1989.

month. For land and desert regions, at least one daytime and one nighttime observation is required. However, even with these minimal requirements, there are still a significant number of regions with no monthly mean clear-sky LW estimate.

The gaps in the ERBE clear-sky flux record are demonstrated by Figure 1. Five years of ERBE ERBS scanner data were combined to calculate the month-to-month variation in the percentage of regions observed that have no monthly mean clear-sky LW flux. It is obvious that pronounced monthly biases exist. For land regions, the percentage varies from 2% to 37% with at least one month from each season showing significantly large clear-sky gaps. This is caused by the use of seasonal mean LW thresholds. The thresholds are clearly too high for some of the months. Similar, but less severe effects are also seen for the ocean and desert regions.

Examination of the ERBE data reveals that the main cause of these clear-sky gaps for land regions is the extreme scarcity of nighttime observations classified as clear. Since there are no SW data to assist in the classification, the clear-sky LW threshold is the sole determinant for scene identification. As can be seen in Figure 1, the same thresholds used in March and May produce quite different results.

The solution to this problem is for the MLE to use more realistic monthly, regional LW thresholds. Since daytime clear-sky classification by the MLE is less dependent on the previously assumed thresholds, we have investigated using the daytime ERBE clear-sky data to produce a new set of clear-sky LW thresholds.

3. NEW REGIONAL CLEAR-SKY LW THRESHOLDS

3.1 Data and method

Five years (1985-1989) of ERBE data from the ERBS scanner were used. For each ERBE 2.5° x 2.5° region and for each month, daytime clear-sky observations were composited into monthly hourly means. The precessing orbit of the ERBS satellite allows for the observation of almost all local times during a month. A least squares fit of the form of equation (1) was performed to derive a value for the noontime clear-sky LW threshold. The diurnal range was assumed to be constant.

This process was performed for both individual months and for 5-year means for each calendar month. Only the 5-year mean results were considered for use in ERBE processing. Although the individual year results compare well with the 5-year means, the noise level of the fits is greatly reduced by using the combined data.

It is assumed that these means can be re-introduced into the ERBE processing as new, more realistic clear-sky thresholds.

3.2 Results

Figures 2a and 2b compare zonal means of the new April thresholds with those currently used in ERBE data processing for ocean and land regions, respectively. The thresholds derived from the ERBE data are significantly lower than the *a priori* thresholds used in the ERBE processing. This demonstrates that the MLE can still successfully classify scenes in the daytime even if the LW thresholds are too high by using the information

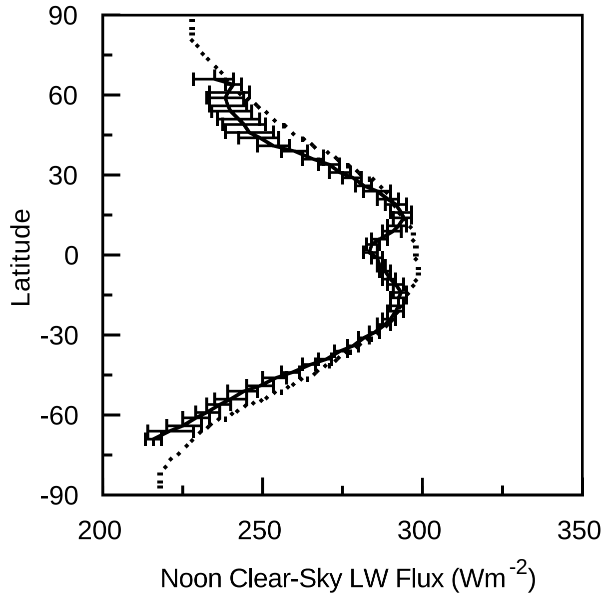

Figure 2a. Comparison of old (····) and new (—) clear-sky ocean LW thresholds for April. Error bars represent one standard deviation for the zonal means.

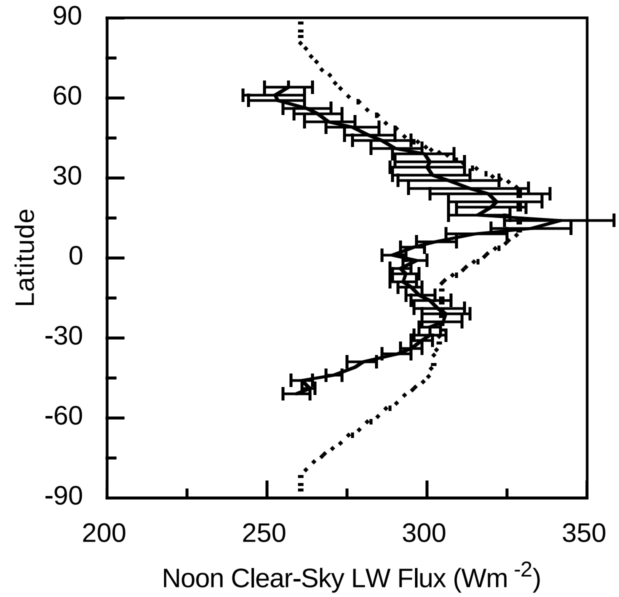

Figure 2b. Same as Figure 2a, but for land regions.

content of the SW observation. It is also apparent that zonal mean thresholds are inadequate. The standard deviation of the derived thresholds exceeds 15 Wm^{-2} for several land latitude bands and is as high as 7 Wm^{-2} for extratropical oceans. The greatest differences between the new and old ocean thresholds occur at the Equator and near 50°N. It appears that the original thresholds have missed real climatic features. These areas have consistently been under-represented in the clear-sky data by ERBE. The land thresholds show a similar pattern, but old-new differences exceed 30 Wm^{-2} in some zones.

4. EFFECTS OF NEW THRESHOLDS ON ERBE MONTHLY MEAN FLUXES

The new clear-sky LW thresholds were used to reprocess ERBE ERBS scanner data for the month of April 1985. As expected, there was a significant increase in scenes classified as clear. The old thresholds had resulted in 555 regions between 60°N and 60°S with no clear-sky data. This was reduced to only 172 regions with the new thresholds. Over land, the difference was due primarily to increased nighttime clear data. For ocean regions, the main improvement was in those zones, such as near the Equator, where the thresholds were most changed.

In order to assess the impact on estimates of the global energy budget, a comparison of global mean total-sky and clear-sky fluxes calculated using the old and new thresholds is presented in Table 1. The LW, SW, and net cloud forcing as defined by Ramanathan et al. (1989) are also included. As is expected, the total-sky values are essentially unchanged. The slight differences are caused by changes in the ADMs selection due to the modified scene identification.

Table 1. Global Mean ERBE ERBS Fluxes for April 1985.

	Old Thresholds	New Thresholds
Total LW (Wm^{-2})	237.9	237.8
Total SW (Wm^{-2})	102.0	102.2
Total Albedo	0.289	0.290
Clear LW (Wm^{-2})	269.5	267.5
Clear SW (Wm^{-2})	54.9	57.5
Clear Albedo	0.143	0.154
LW Cloud Forcing (Wm^{-2})	31.1	29.7
SW Cloud Forcing (Wm^{-2})	-46.5	-44.6
Net Cloud Forcing (Wm^{-2})	-15.1	-15.0
Regions W/ No Monthly LW Clear-Sky	555	172

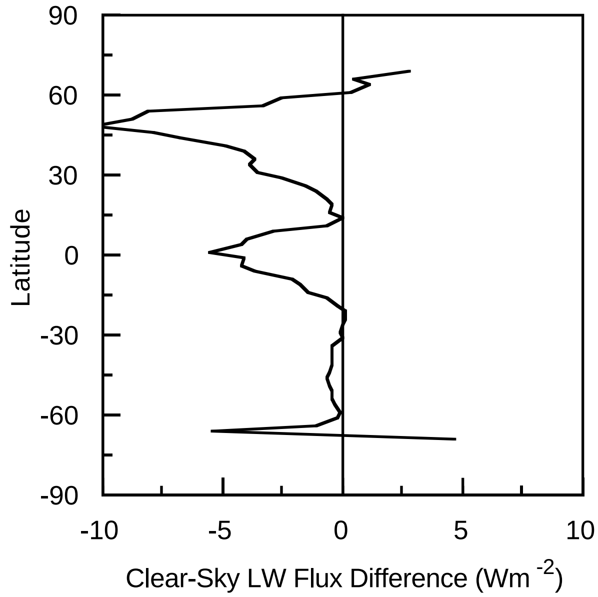

Figure 3a. Change in zonal mean clear-sky LW flux due to the use of new LW thresholds for April 1985 ERBE ERBS data.

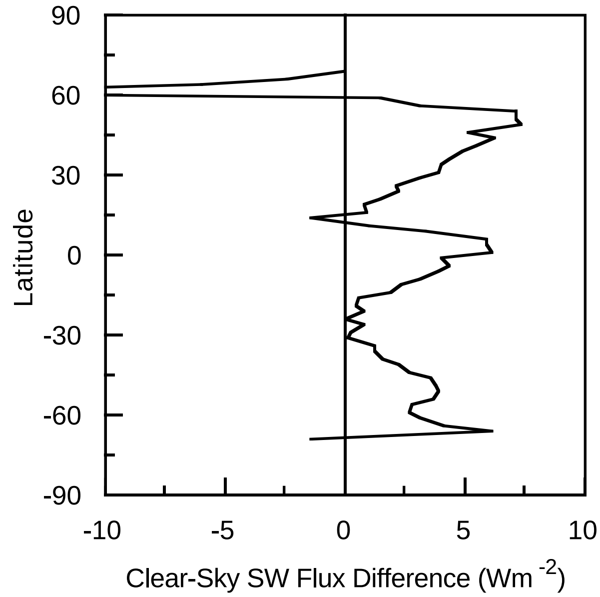

Figure 3b. Same as Figure 3a, but for clear-sky SW flux.

Of course, the greatest change is seen in the clear-sky fluxes. Global mean clear-sky LW and SW fluxes have been changed by 2.0-2.5 Wm^{-2}. The changes are not uniform. Figures 3a and 3b show the zonal distribution of the change in clear-sky LW and SW, respectively. The greatest changes once again occur near the Equator and in the 40°N - 60°N zones where the old thresholds were significantly too high. The magnitude of the largest differences are enhanced because of the inclusion of regions that previously were systematically misidentified as cloudy.

5. CONCLUSION

The primary purpose of the CERES ERBE-like product is to provide the scientific community with a data set that is consistent with the existing ERBE data. No change such as that proposed above will be incorporated in the CERES algorithm unless it is included in a major reprocessing of the ERBE data set. Such a possible reprocessing is currently under consideration.

With a data set as important as ERBE, any change of this magnitude to the processing algorithm must be carefully and thoroughly studied before being implemented. Although this initial analysis does show that the problem of under-classification of clear-sky data has been reduced without any significant effects on the global statistics, these results need to be further analyzed for evidence of cloud contamination of the clear-sky product. In addition, other months (at least one from each season) of data will be processed and analyzed.

Future work includes the possibility of combining the ERBS data with ERBE scanner data from NOAA-9 and NOAA-10. Although care must be taken to account for possible inter-satellite biases, the inclusion of the polar orbiter data will allow for better estimates of the thresholds near the poles.

The possibility of allowing the diurnal range of the LW threshold to vary regionally is also under consideration. This can be easily solved for in conjunction with the noontime LW value, but initial study has revealed that such fits have the potential for excessive noise.

6. ACKNOWLEDGMENTS

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